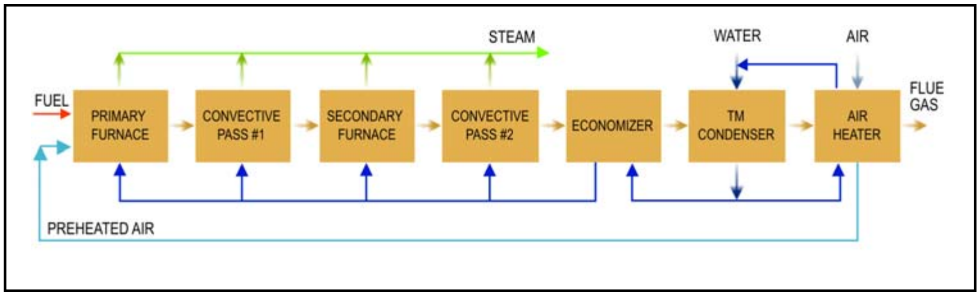
Super Boiler

U.S. industry uses more energy for steam production than for any other single purpose. It costs industry about $18 billion or more annually just to feed the boilers that generate steam, yet industrial steam generation technology has not progressed significantly since the end of the 19th century. An important window of opportunity will open as the aging stock of existing industrial boilers nears retirement. The U.S. manufacturing sector uses more than 33,000 boilers with capacities greater than $10x10^6$ Btu/hr. Of these, over 80% were purchased prior to 1978, with the largest block purchased in the 1960's. About 60% of these boilers are concentrated in just five industries: paper, chemicals, refining, food, and primary metals.

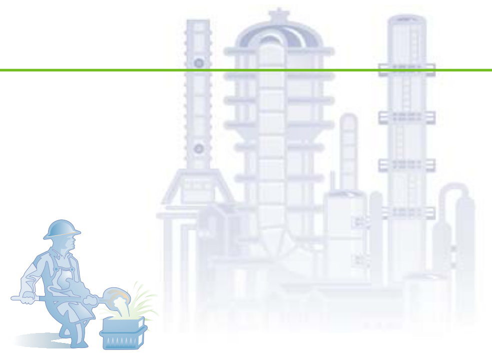
As part of a new Super Boiler program, researchers are working to develop new, breakthrough steam generation technologies that will potentially save U.S. industry over $10 billion annually in operating costs and minimize environmental impacts from steam generation nationwide. The first generation Super Boiler will integrate several novel technologies to achieve extraordinarily high efficiency (>94%) and low emissions (NO_X <5 vppm).

The boiler geometry incorporates a two-stage firetube design that is both compact and highly efficient. Key innovations include a transport membrane (TM) condenser and compact air heater to extract sensible and latent heat from the flue gas for increased energy efficiency; compact convective zones with intensive heat transfer; and a staged/intercooled combustion system for ultra-low emissions.

The First-Generation Super Boiler will be designed and developed for field demonstration under this project. A conceptual diagram of the interconnected boiler system elements is shown below.



This diagram shows Super Boiler innovations such as the transport membrane condenser, convective heat transfer zones, and staged/intercooled combustion. These components of the Super Boiler will dramatically increase energy efficiency and reduce emissions.



Benefits

- 185 trillion Btu/year in energy savings
- $724 million/year in fuel cost savings in the industrial packaged boiler market alone
- $2.2 billion/year in fuel cost savings with extension to field-erected boilers
- Carbon reductions of 2.67 MMTCE
- 25% capital cost reduction
- Compelling economic benefits to accelerate replacement of aging boilers

Applications

Steam is used in almost every manufacturing industry to provide process heat, electricity, and space heating.

Project Partners

- Gas Technology Institute
- Cleaver-Brooks Division of Aqua-Chem Inc.
- GTI Sustaining Membership Program
- Pacific Northwest National Laboratory
- Southern California Gas Company

Project Description

Goal: The first Super Boiler project will ascertain whether the individual advanced technologies (TM condenser, intensive heat transfer, staged/intercooled combustion) meet specifications and perform well in a systems environment. The goal is to then successfully integrate several of the unique, advanced combustion concepts into a technically and economically feasible boiler design.

Performance Targets:

Overall Boiler Efficiency	94%
Stack Temperature	< 150°F
NO_X Emissions	< 5 ppm
CO Emissions	< 5 ppm
VOC Emissions	< 1 ppm
Footprint Reduction	50%

Progress and Milestones

- This R&D project was initiated in July 2000.
- An Industry Advisory Group (IAG) was formed in 2001, and drafted a long-term RD&D Plan to develop a family of future generation Super Boilers by the year 2020; the Plan was submitted to DOE in October 2002.
- A comprehensive evaluation of a broad spectrum of advanced combustion and energy conversion concepts has been conducted to develop a technology vision for future generations of Super Boiler.
- Laboratory development of the TM condenser and compact air heater has advanced; recovery of sensible and latent heat from flue gas corresponding to 94% energy efficiency has been achieved.
- A two-stage intercooled combustion system for the first-generation boiler has been built and tested, demonstrating NO_X levels below 4.0 vppm at 8-12% excess air over a 5:1 turndown. CO levels are below 5 vppm at 25 -100% load, and work is being done to achieve these CO levels at lower firing rates. CFD modeling has also been initiated to support the combustion system design.
- Laboratory testing has confirmed the potential of a microchannel heat exchanger for use as an ultra-compact economizer, which is being integrated with the TM condenser.
- Work is underway on the evaluation of alternative methods of high-intensity heat transfer to reduce size and weight of the boiler.
- Two alternative firetube boiler design approaches have been selected for testing at 3 million Btu/hr, and engineering design has been started. Fabrication of two 3 million Btu/hr laboratory boilers will be completed by September 2003, with installation and evaluation taking place through early 2004. Commercial demonstration is scheduled for mid-2004 into 2005.

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